



Refractory Materials for Flame Deflector Protection System Corrosion Control: Coatings Systems Literature Survey

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1 INTRODUCTION AND OBJECTIVE

When space vehicles are launched, extreme heat, exhaust, and chemicals are produced and these form a very aggressive exposure environment at the launch complex. The facilities in the launch complex are exposed to this aggressive environment. The vehicle exhaust directly impacts the flame deflectors, making these systems very susceptible to high wear and potential failure. An effort is underway to develop or identify new materials or systems such that the wear and/or damage to the flame deflector system, as a result of the severe environmental exposure conditions during launches, can be mitigated. This report provides a survey of potential protective coatings for the refractory concrete lining on the steel base structure on the flame deflectors at Kennedy Space Center (KSC).

This report addresses the potential use of high-temperature and possibly ablative coatings for possible application on the refractory concrete. More specifically, this report will provide a general overview of potential benefits of such coatings, identify potential commercial-off-the-shelf (COTS) products that may be used on the refractory concrete, a general description of protective mechanisms, and recommendations for possible testing of such products. It should be noted that most of the COTS products are proprietary and limited information is available on the composition and/or mechanisms of protection. However, when this information is available, potential benefits and/or challenges will be provided.

In 1994, a protective, ablative coating was applied to areas of the weather protection system at Launch Complex 39B. Following the next five shuttle launches, the protective, ablative coating was assessed and found to reduce launch damage, associated refurbishment costs, and turnaround time. As such, this ablative-type, silicone-based coating was applied to other areas of the launch complex. These silicone-based ablative materials formed a tough surface film when subjected to intense heat and eroded only slightly from the effects of a Shuttle launch. This tough surface coating reduced the refurbishment requirements after each launch and led to more economical use of resources and capital. If an ablative coating can be identified to reduce damage to the refractory concrete during a launch, this technology could provide similar benefits.

Knowing the potential benefits of coatings when exposed to aggressive launch environments, one of the tasks associated with this research are to survey the literature on high-temperature, coatings for possible use on refractory concrete and to identify potential COTS products with the objective of assessing the potential benefits of a coating system for the refractory concrete in the flame trench. The following sections will address these issues.

2 THE REFRACTORY MATERIALS AT KSC

Refractory concrete is a material suitable for use in high temperature environments. Common uses of refractories include line boilers and furnaces of many types - reactors, ladles, stills, and kilns. What is of importance to note in these large-scale applications is that the refractories are placed (commonly gunned) and almost always undergo a “heat-up” procedure.

This heat-up process, a necessary step for good performance, is typically performed during the start-up of the unit and involves heating the unit in a controlled manner. This controlled heat prevents excessive pressurization of entrapped steam after heating above the ebullition point of

water. By preventing heating above the ebullition point, water that exists within the refractory pores (or in combined forms) does not rapidly expand in the pore structure of the refractory, preventing cracking and damage. Although water expansion is prevented, the application of the heat drives the water from the internal pores (and at higher temperatures from the combined state) such that the refractory can dry without causing damage.

Figure 1 shows a relationship between temperature and changes in the microstructure of typical refractories (C is calcium oxide, A is alumina oxide, Al_2O_3 , and H is water). At lower temperatures, as the refractory is drying, the hexagonal calcium aluminate hydrate (CAH_{10}) is converted to the cubic form C_3AH_6 and AH_3 . As the temperature increases, the free water is driven from the pores and at higher temperatures the combined water is driven from the refractory. As the temperature is further increased, ceramic bonding of the refractory particulates occurs, producing a strong, dry product that is resistant to thermal degradation.

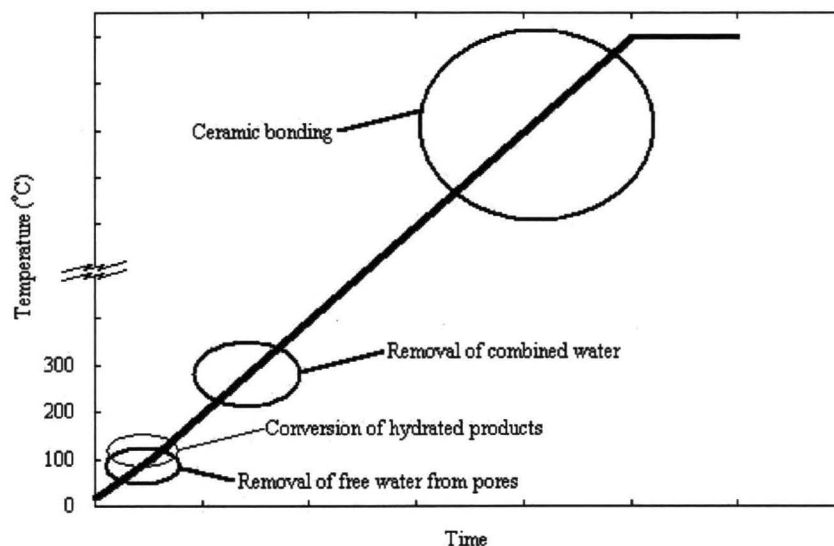


Figure 1. General changes in microstructure of refractories

Important to note is that the refractory concrete placed in the flame trenches does not undergo a controlled heat nor is it dried. Refractories that are not dried and fired can exhibit large variations in performance, typically contain sufficient moisture in the microstructure to cause ebullition of the internal moisture, resulting in cracking or spalling of the refractory.

Several challenges exist in drying and firing the refractories in the flame trenches at KSC. First, if heating occurs from the top exposed face (which would be likely for a system such as the flame deflector), water can be driven further into the refractory (further away from the heated face) and can collect at the steel-refractory interface. Water at this interface can undergo ebullition and can result in larger cracks, spalls, and foreign object debris (FOD) of the refractory lining. This is critical at cracked, spalled, or damaged areas as moisture can collect at these areas while almost being directly exposed to the heat and exhaust from the launch. Issues with uniform, controlled heating of the large area and exposure of the refractory concrete after heating to the Florida environment (rain and high humidity) could eliminate the benefits of the drying and firing process.

The potential for a high-temperature, ablative coating to improve the performance of the refractory lining in the flame trench could be significant. A coating that could prevent the transport of water to the refractory lining, could minimize the transfer of heat to the refractory lining, and can be easily applied, could provide significant value to NASA. The following section provides a list of COTS coatings for high temperature applications. The performance of these coatings in a launch environment is unknown and testing will have to be performed to assess the applicability in the flame trench.

3 COTS COATING SYSTEMS

High-temperature coatings systems have been developed for many applications. The research team searched the literature, the web, industry magazines, and contacted manufacturers to identify as many COTS coatings as practical under the constraints of this project. The majority of the data for this report were obtained from manufacturers' websites. Table 1 shows COTS products identified in this task. A general description of the coatings is provided along with typical application of these coatings. The manufacturer's reported service temperature is also included. Website addresses for the products and companies that sell these products are available in the Appendix. It should be noted that no information on costs were reported and that the economic value of coating systems was not evaluated.

The products shown in Table 1 have been designed and are used for a wide variety of applications. Many of the producers provide only limited information on the products. The Ametek (PPG) (Item 28) and the Minteq (Item 35) products have very high service temperatures (5000 °F), however no or very limited information is provided on other critical properties such as resistance to thermal shock, abrasion/erosion resistance, bonding characteristics, resistance to chemical attack, and others. This is the case for many of the coating products.

It should be noted that a critical property for coatings for use in the flame trench is how the material will be bonded to the refractory concrete lining. Products that do not bond well to this substrate will likely debond during the launch, resulting in more FOD. This characteristic must be evaluated if coatings are considered.

Table 1. COTS high-temperature coatings

No.	Vendor	Product	General product description	Typical use	Service Temp (°F)
1	Wesco Refractories	Ladle Seal G	graphitic parting; excellent resistance to molten metal and slag penetration	refractory working linings	3000
2	Wesco Refractories	Procoat S	resist sulfur attack and penetration	hard refractory linings	3100
3	Aremco	Pyro-Paint™ 634-AS	alumina silica based	ceramic fibers	2300
4	Aremco	Pyro-Paint™ 634-AS/AS1	alumina silica based	ceramic fibers	2300
5	Thermal Ceramics	Unikote M	low/med temperatures, where contaminants are not severe	refractory coating material	2600
6	Thermal Ceramics	Unikote S	med to high temps; use in harsh applications	refractory coating material	3000
7	Mt. Savage	1679 Ladle Wash	high alumina coating with graphite		3000
8	Unifrax	QF series	good adhesion, thermal reflectance, hot gas erosion resistance, resist wetting		2300
	Unifrax	Topcoat Series	excellent flame and hot gas erosion resistance; minimizes thermal shrinkage		2800
9	ZYP Coatings	Zircwash	Silica-free coating, high chemical resistance	Ceramics, Graphite, Metal, etc.	3500
10	ANH/Wessex	Emisshield/ST-1 series	high emissivity ceramic coating	Dense refractories, fire brick, ceramic fiber, most metals	2100 to 3500
11	Emi-coat	emi-coat system D	high emissivity ceramic coating; reduces thermal stresses and shrinkage	dense refractories, firebrick and tile systems	2732
12	Ceracoat (India)		high emissivity ceramic coating; protection of refractory linings; high resistance to aggressive environments	firebrick, monolithics, castables, steel shells	3452
13	Enecoat		silicon carbide based; high emissivity ceramic coating	refractory/ceramic linings	2462
14	Rath	Kerathin	Protective, air setting, high purity emulsions; reduce chemical attack, resist erosion	ceramic fibers	2300 to 3272
15	Polybond (UK)	Furnascote	high zirconia, high resistance to aggressive environments	bricks, monolithics, castables, and steel shells	3470
16	EnergyMax Inc.	Numerous	High and medium emissivity;	refractory and ceramic fiber; metals	3000
17	ZYP Coatings	Z-Guard	excellent chemical resistance; hard, abrasion resistance;	ceramic bodies	3200
18	Solcoat	Green Solcoat	increased corrosion & temperature resistance	ceramic firebrick, cast ceramic, ceramic fiber, stainless steel	3452
19	Solcoat	White Solcoat	increased abrasion resistance	ceramic firebrick, cast ceramic, ceramic fiber, stainless steel	2732

Table1. COTS high-temperature coatings (cont.)

No.	Vendor	Product	General product description	Typical use	Service Temp (°F)
20	JyotiCeramic (India)	Zircoat	good adhesion, good chemical resistance, excellent thermal shock resistance	metal, refractory brick, monolithics, castables, ceramic fiber	3272
21	Hottec	Cercoat 809	resistant to most gases, excellent abrasion resistance	iron, steel	3400
22	Pyrotek				
23	Refractory Shapes Pvt. Ltd.	Refracoat	extremely high resistance to aggressive environments; reduces thermal shock, reduce slag adhesion	firebrick, monolithics, castables, steel shells	3452
24	A-Ten-C		glazing coatings; protects from slag adherence, thermal shock, and chemical attack	firebrick, castables, plastic, rammed surfaces	3600
25	Flamemaster	E-340 AF	areas subject to extreme heat of jet-assisted takeoff; high-temp resistant ablative coating		
26	Flamemaster	F 100E	high-temp resistant ablative coating for use in areas subject to exposure to extreme heat and high erosion		
27	Hi-Tac		elastomeric coating used as ablative liner; low thermal conductivity, high specific heat capacity, good ablation characteristics		3632
28	Ametek (PPG)	T.A.-117	ablative coating and adhesive; excellent thermal insulator		5000
29	Ametek (PPG)	PSX 738	resistant to severe acid conditions and moisture, chemical resistant, excellent adhesion		
30	Amercoat	878	High-temp resistant		
31	SCS	Protek	fire and blast protection system		
32	Fiber Materials Inc	FlexFram 605	two-component ablative coating for blast protection from rocket motor exhaust; thermal and erosive environments		
33	Dow Corning	3-6077 RTV	ablative coating, thermal barrier, high-temp pressurization sealant; protection of launch structures		3300
34	Dow Corning	90-006	aerospace sealant; good ablative and char characteristics, low thermal conductivity		
35	Minteq	Firex RX 2373			5000
36	Hentzen	Zenthane Plus	moisture activated two-component, aliphatic polyurethane coating; aircraft coating		
37	PRC-DeSoto	Korotherm	thermal protective coating; used on rocket launch pads;		
38	Thermo-Lag	3000/3002	when used together, can be used to protect steel from jet fire		
39	Cytac	Ablatives	launch vehicles and missiles		

It is important to note that many of the coating products are available for very specific applications and are considered specialty products. The costs of many of these products and the requirements for installation may make these impractical for use in the flame trench. As an example, the Minteq product (Item 35 in Table 1) noted above is specifically designed for and used on aircraft or rockets and consists of a modified epoxy binder filled with thermally active materials that form cooling gases. Above temperatures of 1000 °F, a charred surface forms that insulates the protected surface by transpirational cooling (this is explained later) and re-radiation. The Havaflex T.A.-117 (Item 28 in Table 1) is a two-component modified phenolic ablative coating and adhesive reported to adhere to almost all types of surfaces that are free of moisture, dirt, or grease. This material was originally developed for use by the U.S. Navy to provide a flexible, trowelable coating material to protect ship decks, bulkheads, and shipboard launchings systems from the extremely high temperatures (up to 5000 °F.) and high gas velocities (up to MACH 3.0) present during missile launch operations and may be a candidate for further investigation.

What is unique to the flame trench application and critical to note for good performance in the flame deflector, is the potential challenges for coating applications. The refractory concrete lining on the steel flame deflector structure undergoes various temperature and humidity cycles – these heating and moisture cycles (from both the Florida and launch environments) move the internal moisture in the refractory concrete. Coatings applied to the refractory lining should ideally be able to transmit water from the refractory to the environment while prevented moisture ingress from the environment to the refractory concrete. Moisture in a coated refractory can lead to spalling of the lining or blistering of the coating, resulting in failure of the protective system – a well-designed and engineered coating with good bond characteristics could provide benefits.

As shown in Table 1, there are a number of potential products for use in the flame trenches at KSC. However, as already noted the exposure conditions in the flame trench during a launch are severe and require unique material characteristics to withstand this environment without damage. Table 1 is not a comprehensive list of potential products but instead a list that shows that products are available for further investigation.

4 MECHANISMS OF THERMAL PROTECTION: A REVIEW

Thermal protection systems are used to keep damaging heat away from the protected base structure. The heat getting to the base structure can be dissipated using several approaches: heat sinks, active cooling, transpirational cooling, radiation cooling, and/or ablation. The following paragraphs will provide a brief description on these mechanisms and how they may apply towards applications in the flame deflector.

Heat sinks typically consist of a material with high thermal conductivity. This material can absorb the heat and distribute it quickly and uniformly away from the protected substrate. However, this method would likely require a significant redesign of the flame deflector and is likely not a feasible option that should be considered.

In high heat flux areas, fluids can be used as a heat sink to dissipate the heat. This method is somewhat already in place at the launch complex as the launch facility is flooded prior to and during launch. Other cooling fluids could include liquid metals and gaseous hydrogen cooling

systems but these fluids are likely not feasible for use in the launch complex. Recent tests at Stennis Space Center found that metal plates with holes drilled uniformly across the surface performed well when a reservoir below the plate was flooded with water and allowed to cover the hot surface of the steel plate during exposure to heat and exhaust.¹ Although these results are promising, challenges at the launch complex would include developing a system to control the corrosion of the steel plates when exposed to the aggressive launch environments (acidic environment) and to the aggressive conditions at the Florida coast. Implementation of such a system could simply change the mechanism of attack from deterioration of the refractory lining to corrosion of the protective base plate (and possibly base structure). A significant amount of engineering and redesign of the flame deflectors would likely be required to implement this option.

Transpirational cooling involves the ejection of a fluid or gas through a porous skin into a boundary layer between the heat flux and the surface, thereby reducing the adiabatic temperature of the surface. Transpirational cooling can be passive or active, depending on the source of the cooling media. Passive cooling could involve the use of an ablating material (described later) underneath a porous skin that upon heating sublimates to produce the cooling gas. Active cooling involves the injection of a fluid from an interior supply vessel through the porous skin and is likely not a feasible method for the protection of the base structure. While such protection schemes are often proposed, the practicality of implementing such a system is poor, especially for the flame deflector.

Radiation cooling consists of reflecting much of the heat flux away from the protected substrate. This mechanism is very effective for orbiting spacecraft because the heat transfer rate is proportional to emissivity and the difference between vehicle temperature and space is a power function. However, reflecting heat from the flame deflector would focus the heat on the launched spacecraft and this concept is likely not feasible.

Ablation is a very effective mechanism of minimizing the total energy a system absorbs. Ablative cooling occurs via heat flux changes when the surface substrate either melts, sublimates, or thermally degrades. The surface mass is carried away in the high-speed flow. Heat is expended both in the material phase changes and when the material is carried away, reducing the conduction of heat to the lower substrate. This general approach is currently being used at other areas on the launch complex and with the refractory concrete in the flame trench and has potential for further uses to make the protective refractory lining more durable. Figure 2 shows possible surface melting of the current refractory material on the flame deflector.² If using an ablative coating (or other coating systems), care must be taken to design the material and system to meet performance requirements specifically for the aggressive launch environment at KSC.

¹ Personal and email communications with N.G. Raines, 1/08/09.

² Eckroft, W., Meyer, A., Sounderrajan, S., and Tanacs, G., STS-126 Pad A – Flame Trench Wall Repair Evaluation: Sensor Quick Look, November 24, 2008 Presentation to NASA.



Figure 2. Possible melting of the refractory concrete surface

Ablative materials work by absorbing heat through a material phase change. A subset of ablators, charring ablators form a charred layer that insulates the base material and at the same time allows the base material to outgas. The out-gassing products can be transported through the charred layer to maximize the thermal protection of the exposed surface (i.e., via transpirational cooling). The charred surface can also block convection heating of the base substrate. Charring ablators can provide multiple levels of thermal protection and may be a reasonable approach as either full-depth liners or as a coating system for the flame deflector.

There are two general strategies to take when designing systems using ablative coatings. The first strategy includes the use of materials that ablate easily. These materials are very effective in removing heat from the exposed system. Examples of low-temperature ablators include simple products such as cork, Teflon, Lucite, fiberglass, nylon, and various urethanes. Intermediate temperature ablators, such as carbon/phenolic and quartz/phenolic materials are in wide use on higher heat flux applications.

The second ablative strategy for designing heat protection coating systems is to use materials that ablate very slowly. Although these materials absorb more energy when they ablate, they tend to ablate at higher temperatures. As an example, a carbon to carbon double chemical bond takes significant thermal energy to break and begins the ablation process. This often leads to the need for more insulation to protect the base structure – for the flame deflector this insulating material could include the refractory concrete. The advantage of high-temperature ablators is that they retain their performance and minimize erosion when subjected to extreme environments.

Various mechanisms of thermal protection have been presented. Ablative coatings may provide improved performance of the refractory lining in the flame deflector systems at KSC. However, care must be taken to identify or design a coating system for the exposure conditions (both the launch and Florida coast environments) in the launch complex at KSC.

5 SUMMARY

This report provided a general overview of coatings for potential use in the flame deflector and provided a table of potential commercial-off-the-shelf (COTS) products for possible use on the refractory concrete lining in the flame deflector. Five different mechanisms for minimizing heat transfer to the refractory lining were reviewed: these included heat sinks, active cooling, transpirational cooling, radiation cooling, and ablation coating systems. Ablative coating systems are available and the potential for implementing such a system at the launch complex may be feasible. However, testing of these coatings under similar environmental conditions found in the flame trench is essential – only after this testing can the feasibility of implementing such a system be determined.

The development of new coatings may also be feasible – a test program on ablative coatings was performed at KSC several years ago with good success. A significant research program is needed to properly evaluate the possible use of a coating in the flame deflectors. It should be noted that if a new, cost-effective refractory material can be developed to resist the harsh exposure conditions found in the flame trenches, and it is determined that the material can be applied and that the system is construct able and repairable, use of a coating system may not be the most efficient option. If the development and testing of coating and refractory systems are assessed, a comparative study will be needed to identify the most economical and safe system.

APPENDIX A. VENDOR AND PRODUCT INFORMATION

No.	Vendor	Product	Website	Data Sheet
1	Wesco Refractories	Ladle Seal G	http://www.wescoi.com/	http://www.wescoi.com/Products/Ladsg.html
2	Wesco Refractories	Procoat S	http://www.wescoi.com/	http://www.wescoi.com/Products/PROCOATS.html
3	Aremco	Pyro-Paint™ 634-AS	http://www.aremco.com/	http://www.aremco.com/PDFs/A5-S_06.pdf
4	Aremco	Pyro-Paint™ 634-AS/AS1	http://www.aremco.com/	http://www.aremco.com/PDFs/A5-S_06.pdf
5	Thermal Ceramics	Unikote M	http://www.thermalceramics.com/	http://www.thermalceramics.com/pdfs-uploaded/datasheets/americas/514-1020.pdf
6	Thermal Ceramics	Unikote S	http://www.thermalceramics.com/	http://www.thermalceramics.com/pdfs-uploaded/datasheets/americas/514-1020.pdf
7	Mt. Savage	1679 Ladle Wash	http://www.mtsavage.com/	http://www.mtsavage.com/PDF/Section%2006%20Mortars%20and%20Coatings.pdf
8	Unifrax	QF series	http://www.fiberfrax.com/	http://www.fiberfrax.com/files/Fiberfrax-Specialty-Products.pdf
	Unifrax	Topcoat Series	http://www.fiberfrax.com/	http://www.fiberfrax.com/files/Fiberfrax-Specialty-Products.pdf
9	ZYP Coatings	Zircwash	http://www.zypcoatings.com/ProductPages/Products.htm	http://www.zypcoatings.com/Datasheets/Zircwash/Zircwash.htm
10	ANH/Wessex	Emissshield/ST-1 series	http://www.hwr.com/	http://www.hwr.com/products/emissshield.html
11	Emi-coat	emi-coat system D	http://www.emi-coat.co.uk/	http://www.emi-coat.co.uk/system_d.html
12	Ceracoat (India)			http://www.alibaba.com/catalog/101640768/CERACOAT_High_emissivity_coating.html
13	Enecoat		http://enecoat.com/	http://enecoat.com/About_Enecoat.html
14	Rath	Kerathin	http://www.rath-usa.com/Home/tabid/36/Default.aspx	http://www.rath-usa.com/LinkClick.aspx?fileticket=zruM1at9Dx0%3d&tabid=82&mid=457&forcedownload=true
15	Polybond (UK)	Furnascote	http://www.acronpaints.co.uk/cgi-bin/polybond/index.html	http://www.acronpaints.co.uk/cgi-bin/polybond/htmlsheets/furnascote/Tech
16	EnergyMax Inc.	Numerous	http://www.energymax.ws/Home_Page.html	http://www.energymax.ws/Coatings.html
17	ZYP Coatings	Z-Guard	http://www.zypcoatings.com/ProductPages/Products.htm	http://www.zypcoatings.com/Datasheets/ZGuard/ZGuard.htm
18	Solcoat	Green Solcoat	http://www.solcoat.com/	http://www.solcoat.com/products.htm
19	Solcoat	White Solcoat	http://www.solcoat.com/	http://www.solcoat.com/products.htm
20	JyotiCeramic (India)	Zircoat	http://www.jyoticeramic.com/index.php	http://www.jyoticeramic.com/zircoat1phy.html#jcip1
21	Hottec	Cercoat 809	http://www.hottec.com/HighPerfor/index.html	http://www.hottec.com/HighPerfor/cercoat809.html
22	Pyrotek		http://www.pyrotek-inc.com/listings.php?id=363	
23	Refractory Shapes Pvt. Ltd.	Refracoat	http://www.refshapes.com/index.htm	http://www.refshapes.com/RefractoryCoatingMaterial.htm
24	A-Ten-C		http://www.ceramicrecycling.com/index.htm	http://www.ceramicrecycling.com/Coatings.htm
25	Flamemaster	E-340 AF	http://www.flamemaster.com/coatings.html	http://www.flamemaster.com/Technical%20PDF/E340AF.pdf
26	Flamemaster	F 100E	http://www.flamemaster.com/coatings.html	http://www.flamemaster.com/Technical%20PDF/F100E.pdf
27	Hi-Tac			http://www.rocketlab.co.nz/high-temperature-ablative-coating.html

28	Ametek (PPG)	T.A.-117	http://www.ametekfpp.com/products/Havaflex.cfm	http://new.ametek.com/content-manager/files/HAV//Havaflex1.pdf
29	Ametek (PPG)	PSX 738	http://ppgamercoatus.ppgpmc.com/index.cfm	http://ppgamercoatus.ppgpmc.com/docs/products/PSX%20738%20Prod.pdf
30	Amercoat	878		http://ppgamercoatus.ppgpmc.com/products/pdf/878_PDS_AI.pdf
31	SCS	Protek		http://www.solentcomposites.com/downloads/ProTek.pdf
32	Fiber Materials Inc	FlexFram 605		http://www.fibermaterialsinc.com/flxfm.htm
33	Dow Corning	3-6077 RTV	http://www.specialtyadhesives.com/dowcorning.htm	http://www.specialtyadhesives.com/dow_sealants/3_6077_RTV.pdf
34	Dow Corning	90-006	http://www.specialtyadhesives.com/dowcorning.htm	http://www.specialtyadhesives.com/dow_sealants/90_006_aerospace_sealant.pdf
35	Minteq	Firex RX 2373	http://www.minteq.com/our-products/minteq-pyrogenics-group/firex-fire-and-thermal-protection-coatings/	http://www.minteq.com/fileadmin/user_upload/minteq/PDF/M-PY-635-AT-1%20FIREX%20RX%202373.pdf
36	Hentzen	Zenthane Plus		
37	PRC-DeSoto	Korotherm	http://www.bergdahl.com/PRC_ByTheNumber.htm	http://www.bergdahl.com/bakorotherm.pdf
38	Thermo-Lag	3000/3002	http://www.carboline.com/products.aspx?OpenView&Start=1&Count=1000&Expand=11.19#11.19	http://msds.carboline.com/website/carbmsds.nsf/(all)/8C595FBBC3E0D4C6852572BF004E08FE/\$file/Thermo-Lag+3002+PDS+3-07.pdf
39	Cytec	Ablatives	http://www.cytec.com/index.htm	http://www.cytec.com/engineered-materials/selectorguide.htm#ablatives